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Montana Highway Commission

ROAD PAMPHLET NUMBER TWO

Drainage of Roads

By GEORGE R. METLEN, *Secretary*
HELENA, MONTANA

April, 1914

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Organized April 4, 1913.

A. W. Mahon, Chairman ..... Helena, Mont.
R. D. Kneale ..... Bozeman, Mont.
George R. Metlen, Secretary ..... Helena, Mont.

Regular meetings of the Board are held the first Friday of each month.

Office—State Capitol, Helena, Montana.

PREFACE.

The following pages have been prepared with the hope they will be read with interest by those who have the care of our roads in charge. Very few of the counties in the State are employing road engineers to supervise the construction of their highways, and it is beyond a possibility for the State Highway Commission or the Highway Engineer at the present time to visit and give assistance in these matters in each and every county. There is a great lack of uniformity in the construction and use of culverts and bridges, and the maintenance and building of drainage systems as applied to roads. Many of those in charge of the road work do not appreciate the need and demand for adequate drainage, with the attendant culverts and bridges, in all road work. This book has been written in such detail as will make it adapted to the use and requirements of the Road Supervisors and attendants.

GEORGE R. METLEN,
Secretary.

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Drainage of Earth Roads

Few States in the Union have so many different road problems to be solved under so many varying and changing conditions, both climatic and soil, as in the State of Montana. Our rain fall varies from twelve inches in some of the eastern portions of the State to as high as twenty-five and thirty inches in some of our western counties. The soils vary from gumbo, through sand, gravel, black loam and in some portions of the State even shifting sand, with all kinds of varying conditions as to grades and topography. All of these soils or formations through which roads are built are subject to the one element, perhaps the most destructive to road maintenance, namely, water.

Soils

For the purpose of treating the subject in as clear and concise a manner as possible soils will be classed as follows:

Heavy Soils.—Those soils known as clayey, gumbo, or argillaceous soils, which would include all classes of soils with a tendency to hold water, which become soft and mirey upon the continued application of water and which break into dust when dry.

Light Soils.—Those soils known as light, sand or silicious soils, and all classes of light washes that have a large amount of fine sand present.

Gravelly Soils.—All soils made up of gravel washes, whether mixed with clay or clean sand wash, that have a large percentage of rock and pebbles in the aggregate.

It is reasonable to say that the greater part of our road trouble is due directly or indirectly to the existence of water. In the sections of the State where the road materials are heavy soils, if the surfaces are not properly drained, ruts and cracks collect water and keep the road in an impassable condition for a longer time than if properly drained. Where the soil may be of light gravelly makeup, particularly in the mountainous portions, the road, if not properly drained, may be eroded, gutters washed out where the torrent follows down the wagon tracks with each rain or freshet. Particularly is this condition most active when the first snow melts in the spring, bringing down large streams of water on the road, which is very quickly made impassable in this manner.

The keeping of the road dry, both above and below, is the most fundamental necessity of a good highway. Fill a clay, gumbo or heavy soil road foundation, no matter how hard, with water and the road surface will soon become wet through capillary action of the soil.

No earth or clay road, however well made otherwise, if water is allowed to collect and remain on it or under it, will remain for any length of time in a passable condition, but will soon become a bog hole. Most roads show a varied alignment and grade, but the chief source of trouble is found in lack of drainage. Miles of most impassable roads can be found at times in different sections of the State which could be kept in a reasonably good condition if properly and thoroughly drained. prompt and thorough drainage is a vital essential to all road construction; particularly to earth roads, drainage is a fundamental necessity.

In a well constructed road there must be provided three separate systems of drainage—(1) surface drainage, (2) side drainage, (3) underdrainage.

Surface Drainage

Surface drainage of a road is provided by crowning the traveled section and keeping it smooth and compact by dragging frequently. The slope from the center to the sides being such that the water will be carried

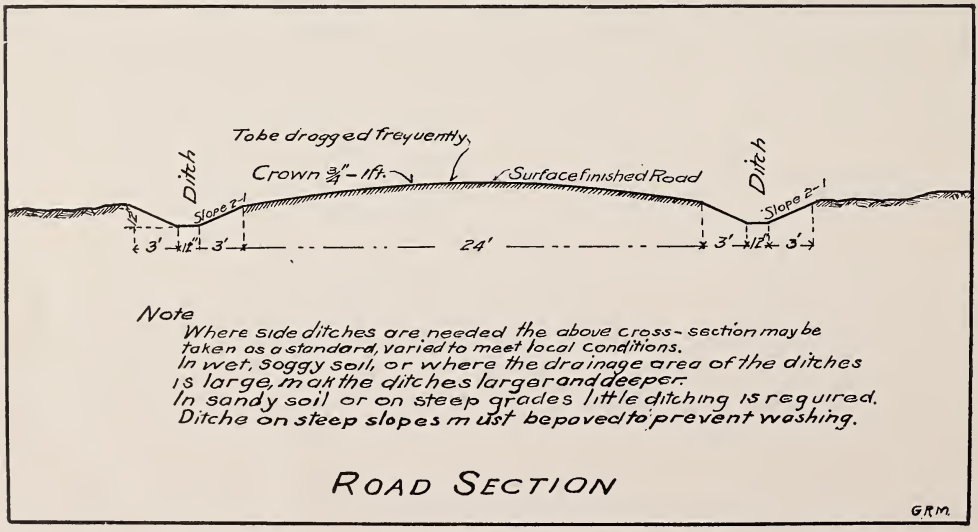

To be dragged frequently.
Crown 3/4" - 1ft.
Surface finished Road
Ditch
Ditch
Slope 2-1
Slope 2-1
3'
1'
3'
24'
3'
1'
3'
Note
Where side ditches are needed the above cross-section may be taken as a standard, varied to meet local conditions.
In wet, soggy soil, or where the drainage area of the ditches is large, make the ditches larger and deeper.
In sandy soil or on steep grades little ditching is required.
Ditche on steep slopes must be paved to prevent washing.
ROAD SECTION
GRM.

FIG. 1

freely and quickly to the side ditches, if the surface is kept free from ruts and holes, less crown will be required. The amount of crown necessary will vary with each particular road and each different kind of soil. Usually three-fourths inch per foot is about the right slope. (See cut No. 1.) A sandy soil does not require as much drainage as adobe, clay or gumbo.

The road builder must study the soil carefully and for each separate problem will be found a different treatment; no fixed or standard cross section can be adopted and expected to give the same results in every case. If there is not enough crown, the water will not flow freely to the side ditches and the road will become water soaked more easily. On the other hand, if the slopes are too steep and the traffic concentrates in the middle of the road it will soon form ruts and holes, which hold surface water to be either absorbed or evaporated. During weather that forms ice or sleet, or when the soil is wet and slippery, there will be a tendency for vehicles to slide into the side ditches if the crown is too steep.

It is important on side hill roads that the surface drainage be collected in uphill ditches and carried to frequent outlets. The ditch on the upper side of the grade should be frequently carried through properly constructed culverts to the lower side. On steep grades where the hills are long it may be found necessary to build checks and drops, or pave with rip-rap or cobble (See cuts Nos. 2 and 3) in the side ditches to prevent the water from washing out and eroding deep gullies. In no instance should drains

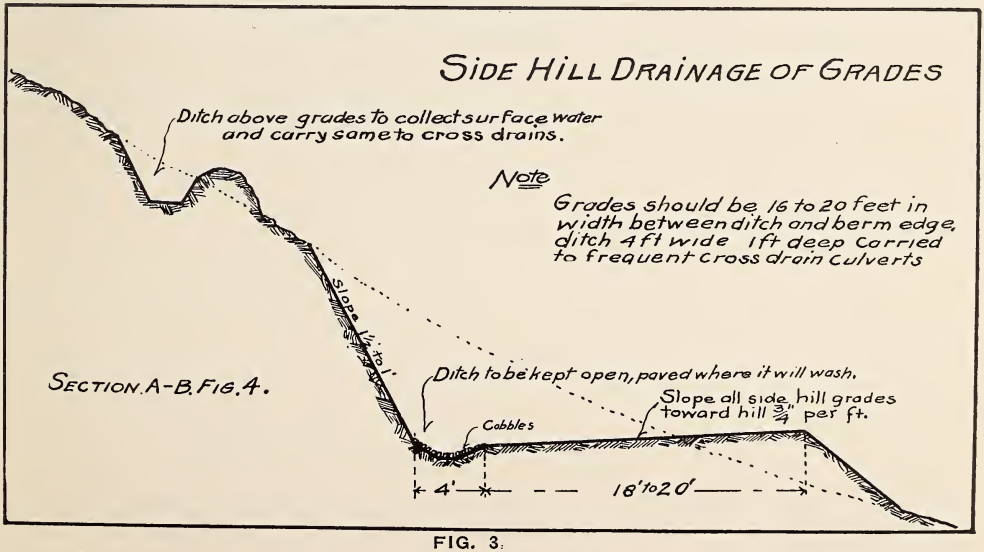

SIDE HILL DRAINAGE OF GRADES
Ditch above grades to collect surface water and carry same to cross drains.
Note
Grades should be 16 to 20 feet in width between ditch and berm edge, ditch 4 ft wide 1 ft deep carried to frequent cross drain culverts
Slope 1 in to
SECTION A-B. FIG. 4.
Ditch to be kept open, paved where it will wash.
Slope all side hill grades toward hill 3/4" per ft.
Cobbles
4'
18' to 20'

FIG. 3.

be carried across the surface of the road. Always place an under cross drain at the lowest place in the drainage system. On hillside roads auxiliary side ditches should be built above all grades as collecting ditches which will carry the surface drainage to cross drains and diminish the amount of water that would drain into the side ditch or the road. (See Fig. 4.) If particular attention is paid to the question of drainage, all ditches carefully laid out and under drains put at the low points in the cross drainage system, the side ditches made on such a grade that water will run to the cross drainage, road maintenance is largely solved.

Another important feature of road drainage is the proper proportion of culverts in the cross drainage system. Care should be exercised in determining the drainage area and the probable maximum amount of water

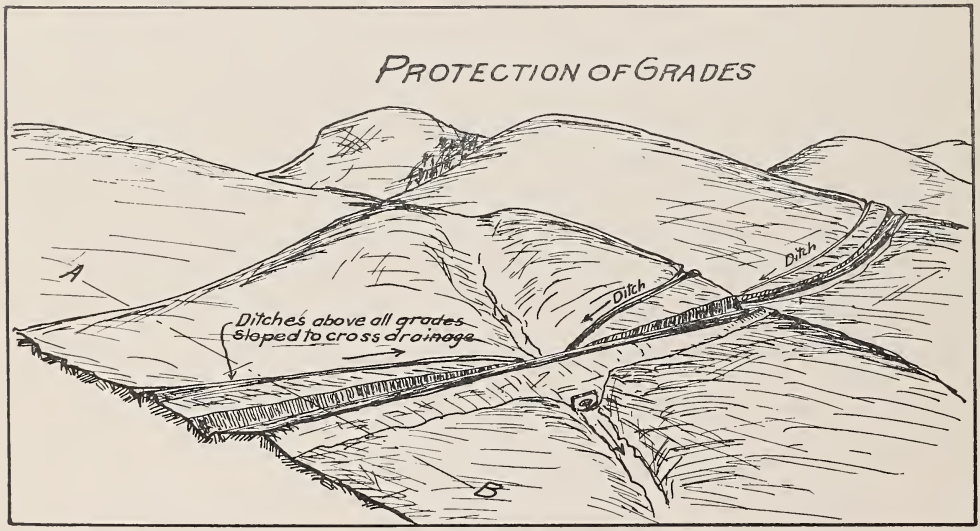


FIG. 4

to be cared for. It is always better that the culvert be built a little too large than too small. In any event the culverts should always be of sufficient size that they will not be clogged with weeds, straw or other debris.

It is not good practice to use culverts less than fifteen inches in diameter, as smaller sizes are easily clogged with straw and weeds and when stopped up defeat the object for which they were placed in the road, causing a washout that is more expensive to repair than the additional cost of a larger culvert in the first instance.

Side Drains

Side ditches parallel with the road are to collect the water drained from the surface of a road and to intercept that which comes from all drainage areas above the line of the road. They should be so graded as to carry the water collected entirely away from the road at frequent cross drains laid in the direction of the general slope of the drainage area.

They should be made wide and flat (See cuts Nos. 1 and 5) so if a vehicle is crowded into the ditch it can easily regain the graded portion of the road. They must have a continuous grade to an outlet. This point

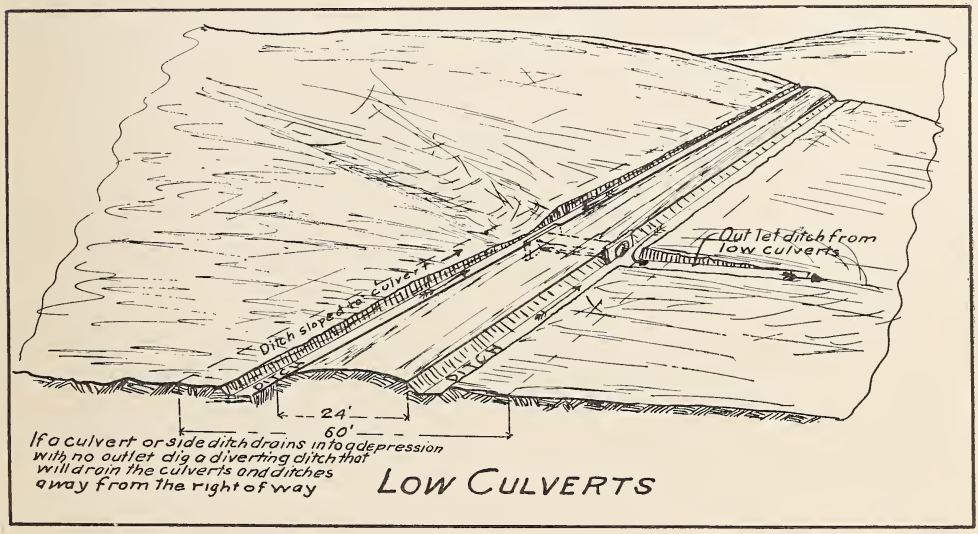

Outlet ditch from low culverts
Ditch sloped to culvert
DITCH
24'
50'
If a culvert or side ditch drains into a depression with no outlet dig a diverting ditch that will drain the culverts and ditches away from the right of way
LOW CULVERTS

FIG. 5

cannot be too strongly emphasized. Don't make a ditch that allows pools of water to stand on the roadside to watersoak the roadbed.

Water should not be carried far along a road before it is given an outlet. All natural water courses should be used as outlets and as many artificial ones formed as necessary to quickly carry all water away from the road.

For example, the property owners living along the line of a road will not object if a very small stream of water is drained from the road on to their premises, but if carried along until such drainage collected in

side ditches becomes a small creek, if drained upon abutting property, trouble will arise if there are no natural water courses large enough to carry it away. In a flat prairie country, where it is practically impossible to secure sufficient grade for outlets from the side ditches, a road must be graded to a sufficient height so that water collecting and standing in the side ditches will never stand nearer than two feet of the top of the grade. The road surface should be higher than this, if possible, to secure good results, if the water stands for any length of time before absorption and evaportion.

Under Drainage

Under drainage provides for the water which seeps through the soil and comes close to the road surface from below. On some roads this

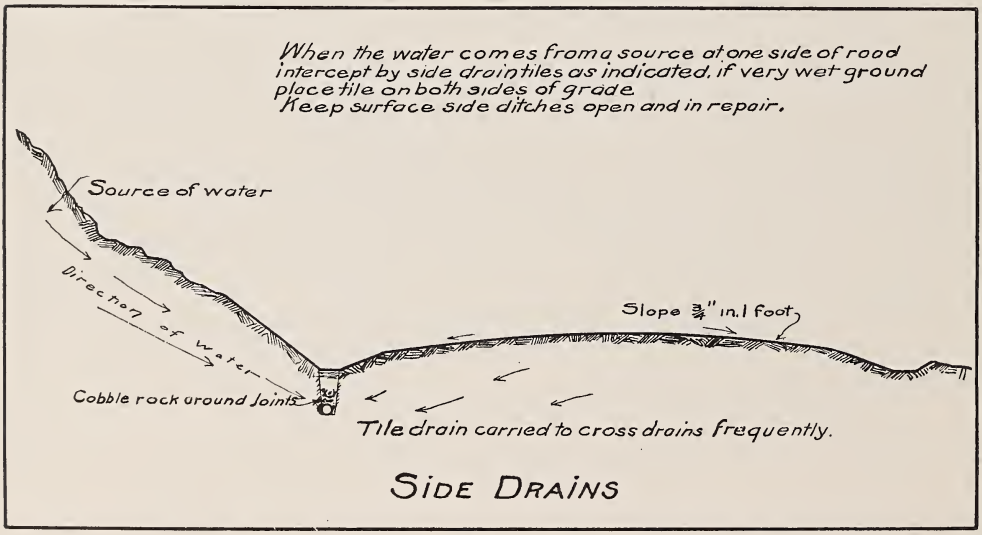

When the water comes from a source at one side of road intercept by side drain tiles as indicated, if very wet ground place tile on both sides of grade.
Keep surface side ditches open and in repair.
Source of water
Direction of water
Slope ¾" in 1 foot
Cobble rock around joints
Tile drain carried to cross drains frequently.
SIDE DRAINS

FIG. 6

water is carried off by the porus nature of the soil. Such may be the case in any sandy and gravelly soils. In the other cases the water does not rise close enough to the surface to make the road cut through, but when it does get close to the surface it causes sink holes and places with apparently no bottom, "bog holes." It is then necessary to drain such a place by artificial means. The presence of this underground water can usually be detected from the signs found along the road itself.

The capillary action of the road material placed above any swampy place will suck the water up to the surface in the same manner that the wick carries oil from a lamp to the burner, the result being the familiar bog or spring hole so frequently found in our roads, particularly in roads passing over sub-irrigated alkali ground. One remedy for such conditions is to construct side ditches of sufficient depth which have grades properly laid so the water will drain to a depth of four feet, if possible, below the crown of the road, to some natural cross drainage course that will carry it away from the road. Owing to lack of fall obtainable it is frequently impossible to drain a road to this depth by side ditches.

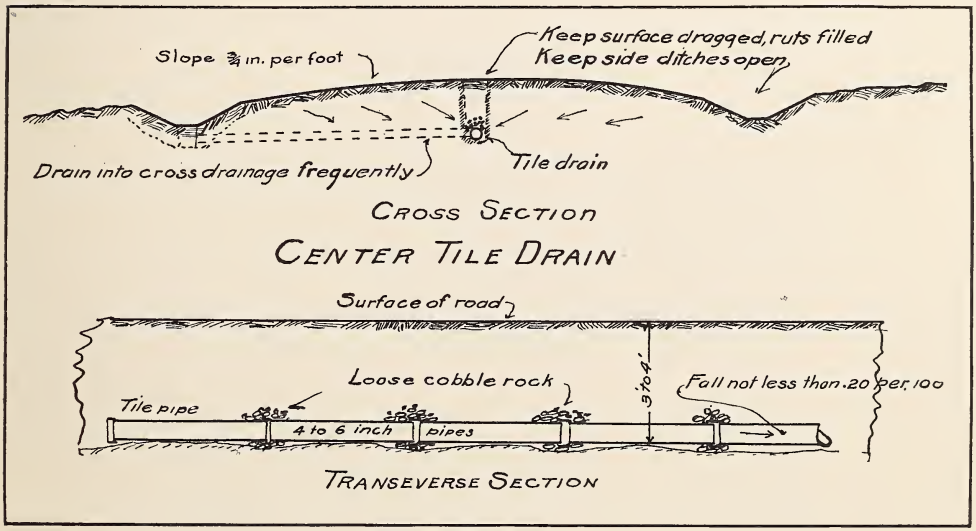


FIG. 7

Whenever a road quakes under heavy loads at all times and becomes nearly impassable in the spring or other wet season, under drains are required. They should be laid with three to six inch vitrified tile (glazed tile preferable, laid with open joints), according to the amount of water and the length of the road to be drained. The best place to put tile is along the ditch on the side of the road from which the seepage comes (See Fig. 6), if on the side hill; and directly along the center of the road, if on a flat or in a cut. (See Figs. 7 and 8.)

Sometimes it may be necessary in very bad places to put tile under each cut at the side. The best method in this case is to put a tile drain along the side of the road which gives the most evidence of the source of under drainage and see if it proves effective. If it is so placd, it should

be laid with its bottom three feet or more below the top of the ground, true to line and grade, its joints carefully surrounded by loose rock, if such rock is available.

If rock is not available, brush may be piled over the joints to prevent them from filling with dirt. The lower end of the tile should be carried down the side ditches to a cross drainage offering a free discharge. All outlets should be protected by wire netting to prevent the entrance of rats or other small animals.

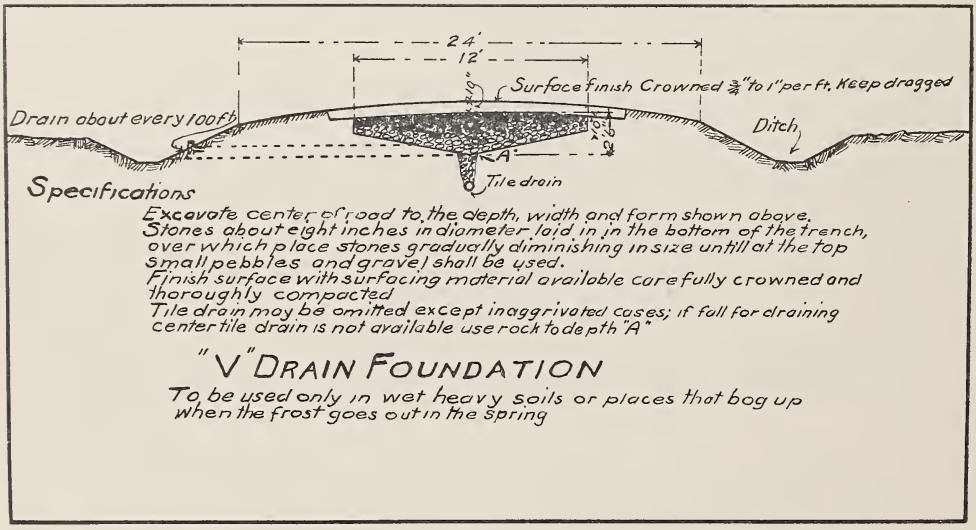

24'
12'
Surface finish Crowned ¾" to 1" per Ft. Keep dragged
Drain about every 100 ft.
Ditch
A
Tile drain
Specifications
Excavate center of road to the depth, width and form shown above.
Stones about eight inches in diameter laid in in the bottom of the trench, over which place stones gradually diminishing in size until at the top small pebbles and gravel shall be used.
Finish surface with surfacing material available carefully crowned and thoroughly compacted
Tile drain may be omitted except in aggrivated cases; if full for draining center tile drain is not available use rock to depth "A"
"V" DRAIN FOUNDATION
To be used only in wet heavy soils or places that bog up when the frost goes out in the spring

FIG. 8

If tile pipe cannot be secured good drains can be made by building a trench and back filling with stones for a depth of one to two feet or by laying brush or small timber in the bottom of the ditch. An effective drain can be built that will serve for the same length of time in this manner.

The tile is the best and cheapest in the long run and if properly laid is indestructible.

Location of the Drains

The drains when placed at the side of the road are usually laid from two and one-half to three feet under the ditch, the depth being governed a great deal by the height to which the ground water rises. If the ground water is very near the surface it may be impossible to lay the tile to this

depth. If the tile is laid under the middle of the road it is more effective than when laid under the side ditch, but more expensive to lay since it necessitates digging along the center of the grade which is probably already built, with a hard surface crust of six to eight inches in thickness. The back filling of the center drain ditch if not very carefully done is apt to cause trouble from settling, making resurfacing necessary. Again if the tile in the center of the road becomes stopped up from any cause it is more expensive to get at to repair than if laid at the side.

In a narrow road, eight to sixteen feet in width, where the water to be moved is under the road bed, the best place for the drain is beneath the center of the driveway; on a wider road two lines of drains may be necessary, placed at the sides. Where the source of the water causing trouble is an under flow adjacent to the highway, the drain should be placed on the upper side of the road. (See Fig. 6.) In aggravated cases it may be necessary to lay a line of drains on either side of the road. Often it may be necessary to place drains to the source of the spring that is causing the trouble and the entire flow diverted in this manner. All the drains should be laid to a true grade which will conform as nearly as possible to the grade of the roadbed, but all drains should be laid to a grade or not less than .20 of a foot per hundred if this can be obtained. All outlets into the surface or cross drainage should have a free fall below the bottom of the drain pipe.

In all cases if tile is used care should be taken to lay it to a true grade, not allowing it to drop anywhere below a rigidly maintained grade line.

If tile is laid in a careless manner water will stand in sags that will occur because of lack of care, and in time these low places will silt up and the drain becomes clogged and useless. Tile from three to six inches in diameter may be used, there being no fixed rule which can be laid down as to the size to use in any case, the quantity of the water present, grade obtainable, and soil condition being the criteria upon which the size of the drain necessary will be based. A little engineering ability coupled with horse sense will in most cases determine these questions.

Roads that Are Too Dry

The preceding paragraph deals entirely with the question of an excess of water. However, for a well maintained earth road, and particularly roads built through light soils, it is just as important that the proper amount of moisture be retained in the body of the road in order to obtain

the proper cohesive properties to hold the particles of the soil together. This is particularly true, and will be noticed during, during the dry seasons of the year. The road becomes dusty, the surface is ground up and eventually if the traffic is heavy, chuck holes and sand holes will form at frequent intervals and the surface will soon become broken up. This is caused primarily by the lack of moisture sufficient to hold the particles together. These conditions can be alleviated by sprinkling.

However, this method is not practical at the present time owing to the great cost. In different sections of the State where the greater portions of the roads are built through a fine alluvial drift considerable trouble is experienced from dust and breaking up of the roads. This is particularly true in certain portions of the Flathead drainage area. However, the County Commissioners of Flathead County have to a certain extent solved this problem by a cheap method of retaining the moisture for a greater length of time in the soils.

Before the road starts to break up, but it is evident by the dry condition that if something is not done soon the dusty, broken conditions will obtain, a covering of straw is placed over the road about four to six inches in thickness. This method and treatment has been carried on in the vicinity of Kalispell for the past two years and is found to be very successful. Ordinary oat or wheat straw which is grown adjacent to almost any of our roads can be obtained usually for the hauling, the cost of spreading being about $4.00 per mile. These straw coverings last, according to traffic conditions, from one to three months, and where carried on for several years the road surface becomes such that moisture is preserved in sufficient quantities to hold the road together for a longer period than before the straw was used. However, straw should never be placed over a mud hole or wet place in a road, as it only serves to hold the moisture in place and keeps the road in a wet condition for a longer period of time than if not used at all.

Culverts

Culverts must necessarily be placed through all roads upon which the semblance of a drainage system is maintained, and it is just as important that all culverts be made of the most lasting and permanent material as that the ditches and drains be well constructed and maintained in repair. A clogged culvert or water passage will defeat the whole purpose of an

otherwise well constructed road drainage system and cause a needless outlay of money by the county and inconvenience to the traveler compelled to use the road.

At present it is neither practical or possible to surface any great amount of our road mileage with either gravel, macadam, stone, or other hard road surface, but it is practical, and from a financial standpoint necessary, that all culverts placed in a road be of the best and most permanent material obtainable consistent with local conditions, such as close railroad facilities for delivery of cement and steel, close proximity of sand, gravel or crushed stone, all of which when present make it of prime importance that waterways be provided with permanent and lasting culverts.

There are through the State a great many miles of roads already graded and crowned, as well as many miles upon which very little money has

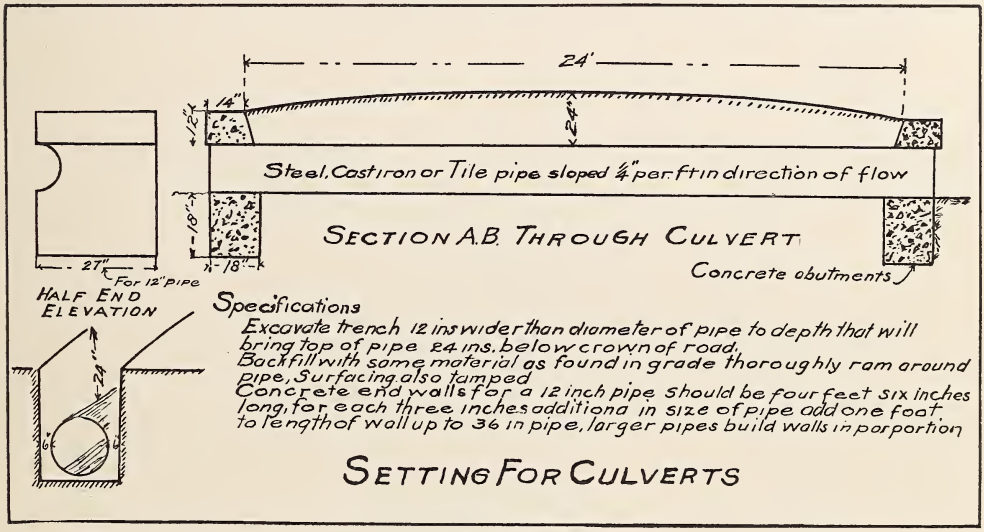
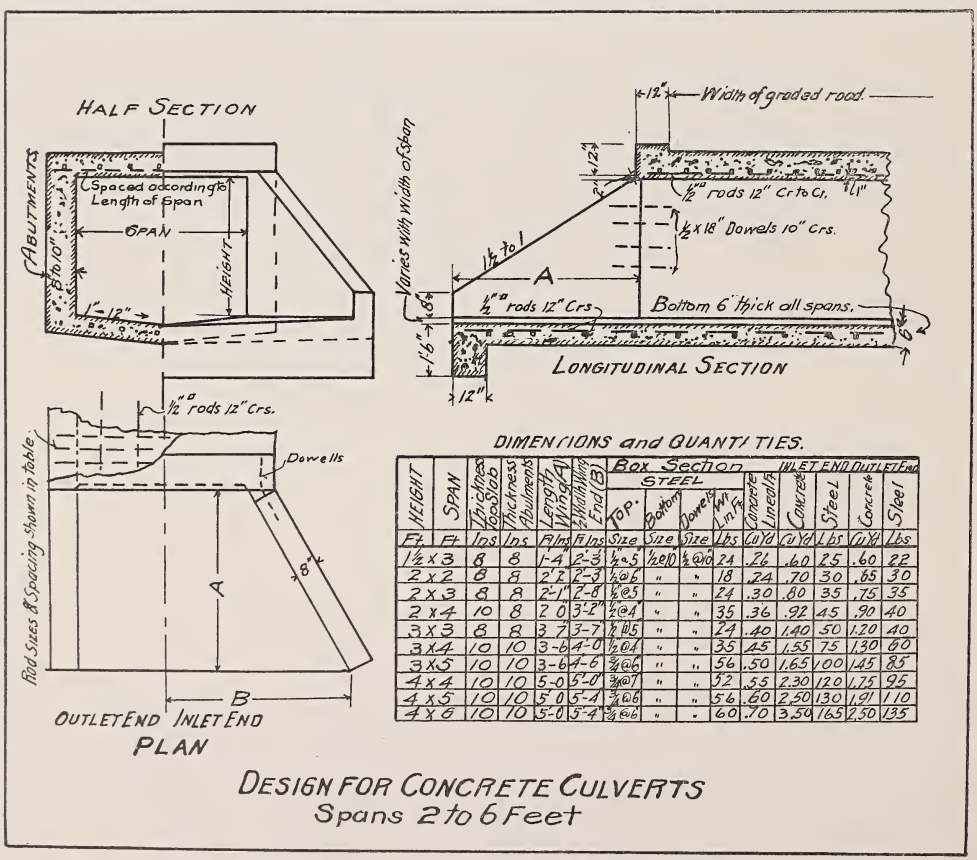

24'
14"
12"
24"
Steel, Cast iron or Tile pipe sloped ¼" per ft in direction of flow
18"
18"
SECTION A.B. THROUGH CULVERT
Concrete abutments
27"
For 12" pipe
HALF END ELEVATION
Specifications
Excavate trench 12 ins wider than diameter of pipe to depth that will bring top of pipe 24 ins. below crown of road.
Backfill with same material as found in grade thoroughly ram around pipe, Surfacing also tamped
Concrete end walls for a 12 inch pipe should be four feet six inches long, for each three inches additiona in size of pipe add one foot to length of wall up to 36 in pipe, larger pipes build walls in porportion
SETTING FOR CULVERTS

FIG. 10

been spent for grading and repairs, through which irrigating ditches and other drainage ways are spanned with wooden culverts. In most instances these wood bridges or culverts are in a continual bad state of repair, are improperly placed and erected, are a continual source of annoyance and expense both to the county and the users of the road. All of such crossings are constantly undergoing repairs and replacements with the same material, and upon roads where traffic is heavy the planking is necessarily renewed each year.

This constant renewal of wooden bridges and culverts under present prices paid for lumber is very uneconomical, unsatisfactory, and with the rapid increase of our road mileage due to settlement and development of the public domain, will soon reach a point where the entire bridge fund will be required to make these temporary repairs. If local conditions will permit, that is a suitable gravel and sand or crushed rock for making concrete, the placing of concrete culverts in all small waterways of from two to ten feet in width cannot be too strongly recommended. A plan for such culverts is herewith appended. This shows approximately quantities of materials required for structures of various sizes. This plan should be varied to suit local conditions and is for the purpose of giving a general idea of the requirements for such a structure. (See Fig. 9.)



DIMENSIONS and QUANTITIES.

HEIGHT	SPAN	Thickness Top & Sides	Thickness Abutments	Length Wings (A)	Width Wing End (B)	Box Section STEEL Top	Bottom	Dowels	Wt. Lin. Ft.	Concrete Lineal Ft.	INLET END Concrete	INLET END Steel	OUTLET END Concrete	OUTLET END Steel
Ft.	Ft.	Ins.	Ins.	Ft. In.	Ft. In.	Size	Size	Size	Lbs.	Cu. Yd.	Cu. Yd.	Lbs.	Cu. Yd.	Lbs.
1½ x 3	8	8	1-4	2'-3"	½ @ 5	½ @ 10	½ @ 10	24	.26	.60	25	.60	22
2 x 2	8	8	2'2	2'-3	½ @ 6	"	"	18	.24	.70	30	.65	30
2 x 3	8	8	2'-1"	2'-8	½ @ 5	"	"	24	.30	.80	35	.75	35
2 x 4	10	8	2 0	3'-2"	½ @ 4	"	"	35	.36	.92	45	.90	40
3 x 3	8	8	3 7	3'-7	½ @ 5	"	"	24	.40	1.40	50	1.20	40
3 x 4	10	10	3-6	4'-0	½ @ 4	"	"	35	.45	1.55	75	1.30	80
3 x 5	10	10	3-6	4'-6	⅝ @ 6	"	"	56	.50	1.65	100	1.45	85
4 x 4	10	10	5-0	5'-0	⅝ @ 7	"	"	52	.55	2.30	120	1.75	95
4 x 5	10	10	5 0	5'-4	⅝ @ 6	"	"	56	.60	2.50	130	1.91	110
4 x 6	10	10	5'-0	5'-9	⅝ @ 6	"	"	60	.70	3.50	165	2.50	135

DESIGN FOR CONCRETE CULVERTS
Spans 2 to 6 Feet

FIG. 9

Concrete for culverts should be mixed of clean material, free from clay, vegetable matter and alkali, mixed with clean water and proportioned as follows: One part fresh Portland cement, two parts sand, four parts crushed rock or gravel of such size that the largest pieces will pass through a ring two and a half inches in diameter, thoroughly mixed on plank platforms or preferably in a mixer. Mix to such consistency that it will run in the forms built for the culvert; when placed in the forms spade away from face to allow fine material to run next to forms.

In building the top slab be sure and place all the concrete in the slab in such a manner that there will be no longitudinal joinings. It is better to place the entire slab at one time, making all end joinings on fresh cement work.

Culverts should stand about five days before taking off forms and should not be opened to traffic until the cement is eight days old at least.

Traction engines should be kept off a long span slab for at least twenty days. Do not allow concrete to freeze in the forms, as it is very liable to be injured to the extent of total failure.

A barrel of cement, four bags, contains 380 to 390 pounds and is usually considered as four cubic feet of cement.

QUANTITY OF MATERIAL REQUIRED FOR ONE YARD OF CONCRETE.

Proportional Parts in Cubic Feet.

Cement	Sand	Rock	Bags of Cement	Sand cu. ft.	Stone cu. ft.
1	2	4	6¼	11¾	23¾
1	3	5	4¾	14	23¼
1	3	6	4½	12¾	25
1	4	8	3½	13	26

Another form of concrete culvert is the unit sectional culvert. This culvert is manufactured in sections that can be handled readily at some point where a sufficient supply of sand, gravel and cement can be economically obtained.

Where economic conditions are right, sand, gravel, cheap transportation and a supply of cement at reasonable quotation, this form of culvert will no doubt give good service.

It can be placed in the road without closing to traffic for a period longer than necessary to do the required excavation work and setting the sections in place. As soon as installed it is ready for traffic, as the sections are cured in the yard where made and arrive on the ground thoroughly seasoned.

Where it is impossible to obtain cement, sand, gravel or crushed rock and sometimes even water for mixing, at a reasonable cost, some of the various forms of corrugated iron culverts should be used in preference to wood culverts. These culverts have come into general use throughout the State in the past few years, but it is found that the proper installation has been gravely neglected. They are generally placed in the road from four to fifteen inches above grade, with a thin covering of dirt placed over them, the result being an uncomfortable high bump is found running across the road, usually with a chuck hole on either side which becomes a mud hole after each rain.

In the placing of pipe culverts the top of the culvert at the crown of the road should be twenty-four inches below the surface. The ends should be set in a buttress wall of concrete or rouble masonry and the outlet end protected in such a manner as to prevent the scouring away of the grades. (See Figs. 9, 10 and 2.)

If material for concrete is not obtainable at a reasonable cost, steel buttresses may be used. These buttresses are manufactured by nearly all of the companies furnishing culvert pipes and furnished at about the same price per pound.

Culverts should always be placed at a low point in the road and if the bottom of the culvert is at such an elevation that it is impossible for the water to drain away from the ditch, an outlet ditch should be dug away from the side ditch in order that such low culverts should drain as indicated in Fgure 5. The general dimensions and instructions for setting pipe culverts is indicated in Figure 10.

The top slab of concrete culverts should have the same depth of covering as any other form of culvert.

If it is impossible to get sufficient depth for a culvert owing to the grade of a ditch or other waterway, the roadbed should be graded up for a sufficient distance on each side to give the required head room and at the same time make a gentle ascent and descent over the culvert crossing.

SIZE OF CULVERTS.

When a culvert is to be installed care should be used to determine the proper size to be placed at the point selected. Look up the size of

the drainage area to be served, determine the greatest amount of water a ditch will carry that crosses the road, and make the waterway opening large enough to take care of the greatest amount possible under extreme conditions of high water flow.

However, it is not good practice to install culverts of less than fifteen inches in diameter, as smaller sizes readily stop up with grass, weeds and other debris and defeat the purpose for which they were intended.

Where a culvert is placed in a road on a hillside to take care of the drainage collected in the uphill ditch the culvert should be placed diagonally across the line of the road pointing in the direction of flow and the steepest grade. (See Fig. 2.) This will prevent clogging at the intake end due to a sudden change in the direction of the current. The outlet ends of such culverts should be rip-rapped to prevent the eroding away of the road on the lower side of the grade.

CARRYING CAPACITY RECTANGULAR CULVERTS FLOWING FULL WITH A FALL OF 1 IN 100.

Size of Culvert	cu. ft. per Sec. Capacity in	Miners' in. Capacity in	ft. per sec. Velicity
1.5x3 feet	18.33	733	4.07
2x2	18.82	752	4.70
2x3	28.23	1129	4.70
2x4	37.64	1505	4.70
3x3	54.84	2073	5.74
3x4	69.12	2764	5.75
3x5	86.40	3456	5.76
4x4	106.56	4262	6.66
4x5	133.20	5328	6.66
4x6	159.84	6393	6.66

CARRYING CAPACITY CORRUGATED PIPE CULVERTS.
Fall of 1 ft. in 50.

Diameter in inches	Capacity cu. ft. per sec.	Capacity in Miners' in.	Velocity ft. per sec.
12	3.34	133	4.25
15	6.23	249	5.07
18	10.20	400	5.77
20	13.36	530	6.12
24	22.28	891	7.09
30	41.13	1645	8.37
36	67.51	2700	9.55
42	102.27	4090	10.62
48	146.39	5855	11.60
60	266.04	10641	13.55
72	430.03	17200	15.22

Calculated by Kutters Formula, n=.017.

A universal mistake is made in placing culverts across a wide grade, only sixteen feet in length. It is just as important that the culvert be the full width of the grade as it is of sufficient capacity to carry drainage served thereby.

A road graded and crowned anywhere from eighteen to thirty feet in width between ditches with bridges and culverts only sixteen feet in width crossing it at frequtnt intervals is very hard to maintain. When it is dragged the team must pull into the center at each crossing or fill up the cross ditch. A grader can not be used for cleaning the side ditches with any degree of efficiency, and lastly the open ditch leading to each culvert is liable to cause accidents by vehicles missing the end of the short bridges at the contracted crossings.

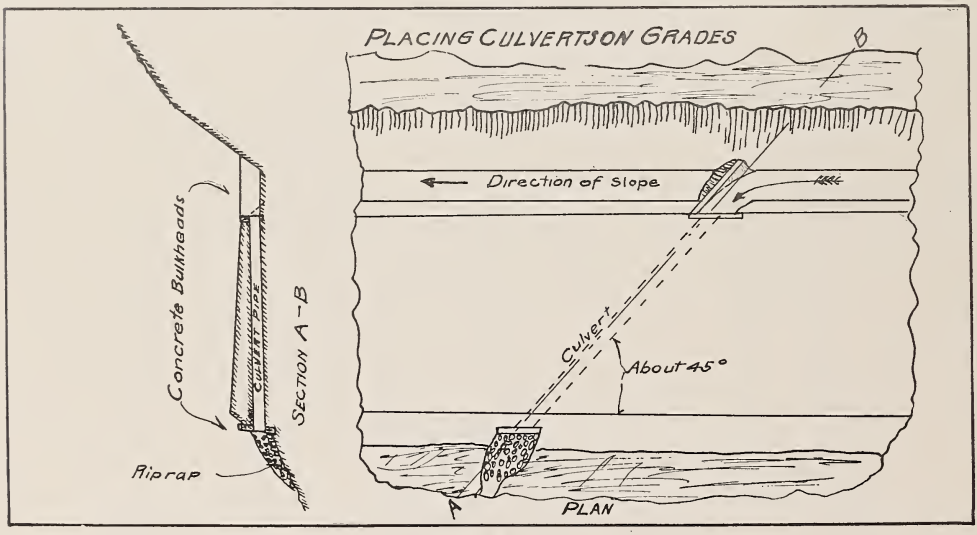
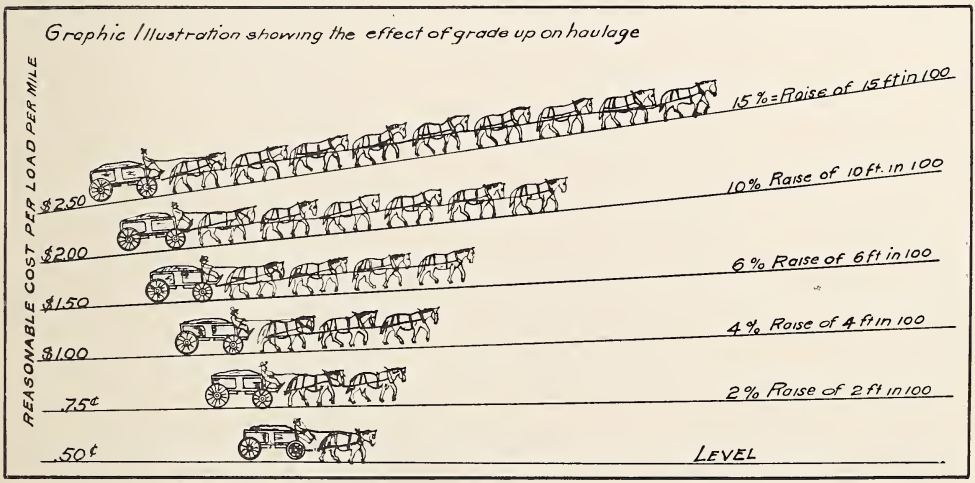


FIG. 2

INFLUENCE OF GRADE AND SURFACE.

The influence of grades on cost of tonnage is illustrated by the following graphic illustration. The load you can haul to market is the load you can pull over the steepest grade on a road, which may be only a half load for the road the greater part of the distance to be traveled.

The estimated cost of hauling one ton a distance of one mile by horses and wagon upon different classes of roads is illustrated by the annexed table. (Table prepared by Joseph Hyde Pratt of the North Carolina Geological Survey.)


Graphic Illustration showing the effect of grade up on haulage
REASONABLE COST PER LOAD PER MILE
$2.50
$2.00
$1.50
$1.00
.75¢
.50¢
15% = Raise of 15 ft in 100
10% Raise of 10 ft. in 100
6% Raise of 6 ft in 100
4% Raise of 4 ft in 100
2% Raise of 2 ft in 100
LEVEL

	Cents.
On iron rails	.0128
On asphalt road	.27
On stone paving, dry, in good order	.27
On stone paving, ordinary repair	.12
On stone paving, covered with mud	.21
On broken stone road, dry and in good order	.08
On sand clay road in good order, dry	.08
On broken stone, road, moist, good order	.103
On broken stone road, ordinary condition	.119
On broken stone road, covered with mud	.143
On broken stone road, muddy and rutty, bad repair	.26

On dry hard earth road, not dusty	.18
On earth roads, with ruts and mud	.39
Gravel roads, loose	.516
On gravel roads, compact	.12
On plank roads, good order	.088
On wet sand	.326
On dry sand	.640

CONCLUSION.

In conclusion will add that good roads are only obtained at the cost of eternal vigilance. A road, no matter how well built or of what material, if not maintained will soon go to pieces under traffic. The surface will be washed away during the rainy season and blown away during the dry. Where a road is properly constructed of whatsoever materials maintenance must be immediately started to keep it in condition; that is, the water must be carefully kept off the road and the crown kept up in sufficient repair so that the surface water will drain off quickly.

All the hillside intercepting ditches kept open and in repair.

Keep the weeds and debris clear from the side ditches.

See that all culverts and ditches are kept open.

If holes are found in the road, mud holes or dust holes, repair them with the same material as that of which the road is constructed.

Do not fill a hole with rock, brush or other material different from that of which the road is constructed. If a hole in an earth road is filled with rock or gravel the result will be that two holes will be formed, one on each side of the hard filling, due to wheels jumping off the hard spot on to the softer material.

In order that the best surface conditions may be obtained drag the road in the spring when it is beginning to dry, drag it whenever there is a wet spell throughout the season.

The best results can only be obtained by methods of system, and vigilance. Co-operation is necessary and in this spirit this department offers its aid that its purpose may be best fulfilled to the best interests of the people in general.

Adopted by the Montana Highway Commission, March 28th, 1914.

GEORGE R. METLEN,
Secretary Montana Highway Commission.